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# APPLICATION FOR UNITED STATES LETTERS PATENT

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For: HEAT CONTROL DEVICE
Docket No.: NU-98035

APPLICATION
FOR
UNITED STATES PATENT

To Whom It May Concern:

BE IT KNOWN that We, Akira OKAMOTO, Yuichi SHIMAKAWA and Takashi MANAKO, citizens of Japan, all residing at c/o NEC Corporation, 7-1, Shiba 5-chome, Minato-ku, Tokyo, Japan, have made a new and useful improvement in "HEAT CONTROL DEVICE" of which the following is the true, clear and exact specification, reference being had to the accompanying drawings.

# HEAT CONTROL DEVICE

## BACKGROUND OF THE INVENTION

The present invention relates to a ~~heat~~ thermal control device and more particularly to a ~~heat~~ thermal control device feasible for, e.g., an artificial satellite or a spacecraft.

As for ~~a~~ spacecraft expected to navigate ~~a~~ in vacuum environment, ~~heat~~ thermal radiation from ~~outside~~ external surfaces is the only heat ~~radiating~~ rejection means available. The amount of ~~heat~~ thermal radiation dictates the temperature inside the spacecraft. A thermal louver has ~~customarily~~ conventionally been used for maintaining temperature inside the spacecraft adequate. The thermal louver adjusts the amount of ~~heat~~ thermal radiation to the outside in accordance with temperature. Specifically, the louver assembly includes a bimetal or similar actuator for driving blades. The blades are movable to increase or decrease the effective ~~area~~ radiation and therefore regulate the temperature of ~~heat~~ thermal radiation surfaces, i.e., increase the amount of ~~heat~~ thermal radiation at a high temperature or reduce~~s~~ it at a low temperature.

However, the above thermal louver is a mechanical device including movable ~~portions~~ portion and therefore bulky and heavy. Moreover, the louver lacks in reliability for long life application due to the movable portion~~s~~. In addition, the blades cannot be opened and closed more than a

~~preselected number of times due to their limited life.~~

Technologies relating to the present invention are also disclosed in~~, e.g.,~~ Japanese Patent Laid-Open Publication Nos. 63-207799, 1-212699 and 9-58600.

## SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a reliable thermal ~~heat~~ control device operable over a long period of time, even in a severe environment, ~~environment~~ that is and easy to produce.

It is another object of the present invention to provide a reliable, small size and light weight thermal ~~heat~~ control device having ~~including~~ no movable portions.

In a thermal ~~heat~~ control device of the present invention, a variable-phase substance exhibiting emissivity properties ~~a property~~ of an insulator ~~or a property of metal~~ in a high temperature phase a ~~or~~ a low temperature phase, ~~respectively,~~ and radiating a great amount of heat a ~~or~~ a small amount of heat in the low temperature phase ~~or the high temperature phase, respectively~~. controls the temperature of a desired object.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description taken with the accompanying drawings in which:

FIG. 1 shows a conventional thermal louver;

FIG. 2 is a graph showing a reflection spectrum particular to

a variable-phase substance $La_{1-x}Sr_xMnO_3$ applicable to the present invention;

FIG. 3 is a graph showing ~~resistivity~~ data representative of the emissivity of $La_{1-x}Sr_xMnO_3$

FIG. 4 is a graph showing data representative of the ~~reflectivity~~ resistivity of $La_{1-x}Sr_xMnO_3$; and

FIGS. 5 and 6 respectively show a first and a second embodiment of the ~~heat~~ thermal control device in accordance with the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

To better understand the present invention, brief reference will be made to a conventional thermal louver, shown in FIG. 1. The thermal louver to be described adjusts the amount of ~~heat~~ thermal radiation to the outside in accordance with temperature, as stated earlier. As shown, the thermal louver includes a bimetal or actuator 10 and blades 12. The bimetal 10 drives the blade 12 in order to increases or decreases the effective area and therefore the temperature of ~~heat~~ thermal radiation surfaces. There ~~are~~ is also shown in FIG. 1 a frame 14, a bimetal housing 16, shafts 18, and bearings 20.

A ~~heat~~ thermal control device in accordance with the present invention is characterized in that it uses a ~~heat~~ thermal radiation characteristic particular to a ~~substance~~ material itself in place of a mechanical principle. As for a spacecraft expected to navigate a vacuum environment, ~~heat~~ thermal radiation from ~~outside~~ external surfaces is the only heat ~~radiating~~ rejection means available. The amount of heat radiation dictates the temperature inside the spacecraft.

The ~~heat~~ thermal control device of the present invention is implemented by a variable-phase substance ($La_{1-x}Sr_xMnO_3$) arranged on the heat radiation surfaces of a spacecraft. The variable-phase substance belongs to a family of oxides of perovskite Mn and undergoes phase transition around room temperature. The emissivity characteristics of this material ~~kind of substance~~ are ~~is~~ similar to that of a ~~the characteristic of~~ metal in a low temperature phase, and ~~but~~ similar to the emissivity characteristics of an insulator in a high temperature phase. Also, the emissivity ~~heat radiation ratio~~ of the substance is low when conductivity is high, but high when conductivity is low. The substance therefore has an automatic temperature adjusting ability, i.e., automatically increases its emissivity ~~heat radiation ratio~~ at high temperatures and decreases it at low temperatures. FIG. 1 shows the dependency of the resistivity and infrared reflectivity of $La_{1-x}Sr_xMnO_3$ on temperature, reported in the past. As FIG. 2 indicates, the reflectivity noticeably changes with changes in temperature around photon energy of about 0.12 eV (10 ~~μm~~ micro meter) which is the peak of ~~heat~~ black body radiation around room temperature. The phase transition temperature is variable between 250 K and 350 K in accordance with the composition ratio $x$ of La and Sr.

FIG. 3 shows data representative of the hemispherical emissivity ~~reflectivity~~ of $La_{0.825}Sr_{0.175}MnO_3$ and measured in the range of from 170 K to 380 K. As shown, the emissivity ~~reflectivity~~ sharply changes in the range of from ~~300~~ 200 K to 280 K, i.e., at the phase transition temperatures. As a result, the above substance exhibits the emissivity characteristics of metal at the low temperature side, but exhibits the characteristic of an

insulator at the high temperature side.

FIG. 4 shows data representative of the result of measurement of resistivity. As shown, the resistivity changes by about four times as in FIG. 2.

In the ~~heat~~ thermal control device of the present invention, the variable-phase substance should only be arranged on heat radiation surfaces in the form of a film and is therefore space-saving and light weight. Moreover, the device is highly reliable because ~~it needs~~ there are no movable portions. When the device is mounted in a position getting the sunlight, a silicon plate transparent for thermal infrared rays, but opaque for the sunlight, may be positioned in front of the variable-phase substance in order to minimize the sunlight absorption of the device.

For the variable-phase substance, use may be made of an oxide of Mn-containing perovskite represented by $A_{1-x}B_xMnO_3$ where A denotes at least one of La, Pr, Nd and Sm rare earth ions, and B denotes at least one of Ca, Sr and Ba alkaline rare earth ions. Further, such a substance may be implemented by an oxide of Cr-containing corundum vanadium, preferably $(V_{1-x}Cr_x)_2O_3$.

Referring to FIG. 5, a first embodiment of the ~~heat~~ thermal control device in accordance with the present invention will be described. As shown, the device is implemented by a variable-phase substance 1 for controlling the temperature of a desired object 2. The substance 1 exhibits the emissivity characteristics of metal in a high temperature phase, and ~~but~~ exhibits the emissivity characteristics of ~~an insulator~~ metal in a low temperature

phase. Also, the substance 1 radiates a great amount of heat in the high temperature phase, but radiates a small amount of heat in a low temperature phase. The substance 1 is affixed to the object 2 by powder coating, ~~evaporation~~ deposition, crystalline adhesion or similar affixing means. In the illustrative embodiment, the substance 1 is implemented by $La_{1-x}Sr_xMnO_3$ belonging to a family of oxides of perovskite Mn.

Specifically, the object 2 is representative of the heat radiation wall of ~~a~~ spacecraft. The substance 1 is arranged on the surface 3 of the wall 2 in the form of a several hundred micron thick film. The substance 1 is thermally coupled to the surface 3 and substantially the same in temperature as the wall 2.

In operation, when the temperature of the surface 3 rises and heats the substance above the phase transition temperature, then the ~~heat radiation ratio~~ emissivity of the substance increases. As a result, the amount of ~~heat~~ thermal radiation to the outside environment increases and lowers the temperature of the surface 3. Conversely, when the temperature of the surface 3 drops and cools off the substance below the phase transition temperature, the heat radiation ratio of the substance 1 and therefore the amount of ~~heat~~ thermal radiation decreases, raising the temperature of the surface 3. With this mechanism, the substance 1 automatically controls the temperature of the surface 3 to a range around its phase transition temperature.

The substance 1 has a nearly cubic crystal structure and has an optical property not dependent on the orientation of the

crystallographic axis. It follows that the substance 1 can be arranged on the surface 3 by any one of conventional schemes including powder coating, ~~evaporation~~ deposition, crystalline adhesion and other affixing means and the adhesion of a film implemented by a powdery phase-variable substance containing, e.g., a binder.

The illustrative embodiment is practicable only if the variable-phase substance is implemented by, e.g., an oxide of Mn-containing perovskite represented by $A_{1-x}B_xMnO_3$ where A denotes at least one of La, Pr, Nd and Sm rare earth ions, and B denotes at least one of Ca, Sr and Ba alkaline rare earth ions. Further, such a substance may be implemented by an oxide of Cr-containing corundum vanadium, preferably $(V_{1-x}Cr_x)_2O_3$.

A second embodiment of the ~~heat~~ thermal control device in accordance with the present invention will be described with reference to FIG. 6. As shown, the device is also implemented by the variable-phase substance 1 for controlling the temperature of the object 2. The substance 1 exhibits the emissivity characteristics of ~~metal~~ an insulator in a high temperature phase, ~~but~~ and exhibits the emissivity characteristics of ~~an insulator~~ metal in a low temperature phase, as stated earlier. In addition, the substance 1 radiates a great amount of heat in the high temperature phase, but radiates a small amount of heat in a low temperature phase, as also stated previously. In the illustrative embodiment, a silicon plate 4 transparent for infrared rays, but opaque for visible rays, is positioned on the substance 1.

As shown in FIG. 2, $La_{1-x}Sr_xMnO_3$ constituting the substance 1

has reflectively as low as about 0.2 in the sunlight wavelength range a (0.3 ~~μm~~ micro meter to 2.5 ~~μm~~), i.e., it shows high ~~absorbance~~ absorptivity to the sunlight in such a range. Therefore, when the substance is positioned in an area directly getting the sunlight, its ~~absorbence is increased to obstruct heat radiation~~. In such a case, as shown in FIG. 6, the silicon plate 4 transparent for infrared rays, but opaque for visible rays, is mounted on the front of the substance 1. This embodiment is therefore identical in principle with the first embodiment except that the silicon plate 4 reflects the sunlight.

If desired, the silicon plate 4 may be replaced with any other member, e.g., a plate or a film containing germanium so long as it can transmit infrared rays.

In summary, it will be seen that the present invention provides a a small size, light weight ~~heat~~ thermal control device using an optical property particular to a substance itself in place of a mechanical principle applied to a conventional thermal louver. In addition, the device of the present invention is highly reliable and long life because it needs no moveable portions which would bring about wear, fatigue and other problems.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.